MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2022/2023 (TERM ID 2220)

EEE2146 – MICROELECTRONIC CIRCUIT ANALYSIS AND DESIGN

(All Sections / Groups)

12 JULY 2023
9.00 a.m. - 11.00 a.m.
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of SIX pages including cover page with FOUR questions only.

2. Attempt all questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please print all your answers in the answer booklet provided.

Question 1

(a) Referring to the circuit shown in Figure Q1, sketch the DC equivalent circuit. Design the biasing circuit by finding the resistor R_E, given that the emitter current, $I_E = 3.8$mA. Then, find the base voltage, V_B. Note that, the VCC = 10 V, the transistor $V_{BE\,(active)} = 0.7$ V, current gain $\beta = 100$, the early voltage $V_A = \infty$, $R_B = 200$ kΩ, $R_L = 1$ kΩ and $R_S = 50$ Ω. [7 marks]

(b) Sketch the mid-band AC small-signal equivalent circuit of the amplifier circuit shown in Figure Q1, using the simplified T-model, excluding r_o. [5 marks]

(c) From the small-signal equivalent circuit in part (b), determine:
(i) small signal input resistance, R_{IN}, [6 marks]
(ii) voltage gain, $A_V = \frac{V_O}{V_{IN}}$, [4 marks]
(iii) overall voltage gain, $G_V = \frac{V_O}{V_{Sig}}$. [3 marks]
Note that, voltage equivalence of temperature $V_T = 26$ mV.

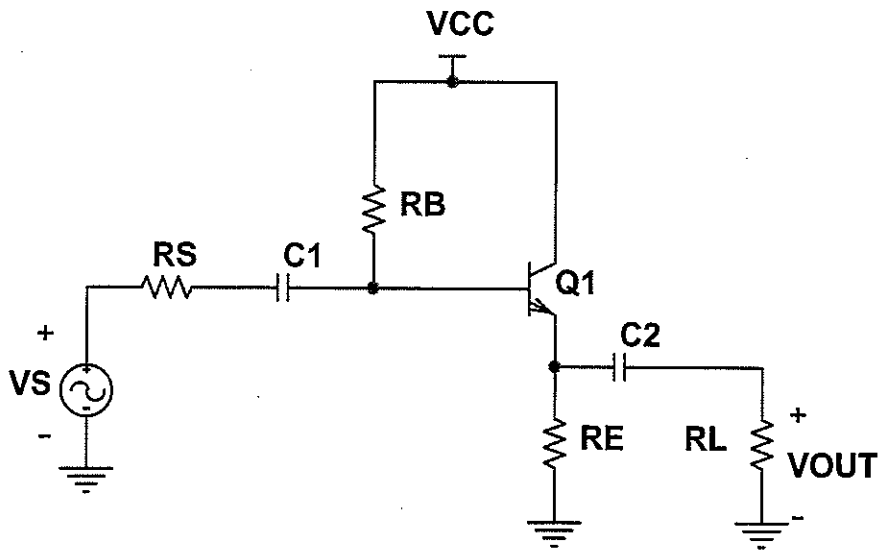

Figure Q1

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Question 2

The circuit shown in Figure Q2 is a common source amplifier. The NMOS transistor has $V_t = 0.5$ V, $k'_n(W/L) = 0.888$ mA/V^2 and $\lambda = 0$. The biasing current is $I_D = 1$ mA. Note that, $V_{DD} = 5$ V, $R_1 = R_2 = 5$ MΩ, $R_S = 0.5$ kΩ, $R_D = 2$ kΩ, $R_L = 8$ kΩ and $R_{sig} = 50$ Ω.

(a) Draw the DC equivalent circuit of the circuit shown in Figure Q2. From the DC analysis, show that the transistor is operating in the saturation region. [11 marks]

(b) Draw a small-signal equivalent circuit for the circuit shown in Figure Q2 using the simplified hybrid-π model (without r_o). [5 marks]

(c) Refer to the small-signal equivalent circuit in part (b), determine;
(i) the small-signal input resistance, R_{OUT}, [2 marks]
(ii) the small-signal voltage gain, $A_v = \frac{v_o}{v_{in}}$. [7 marks]

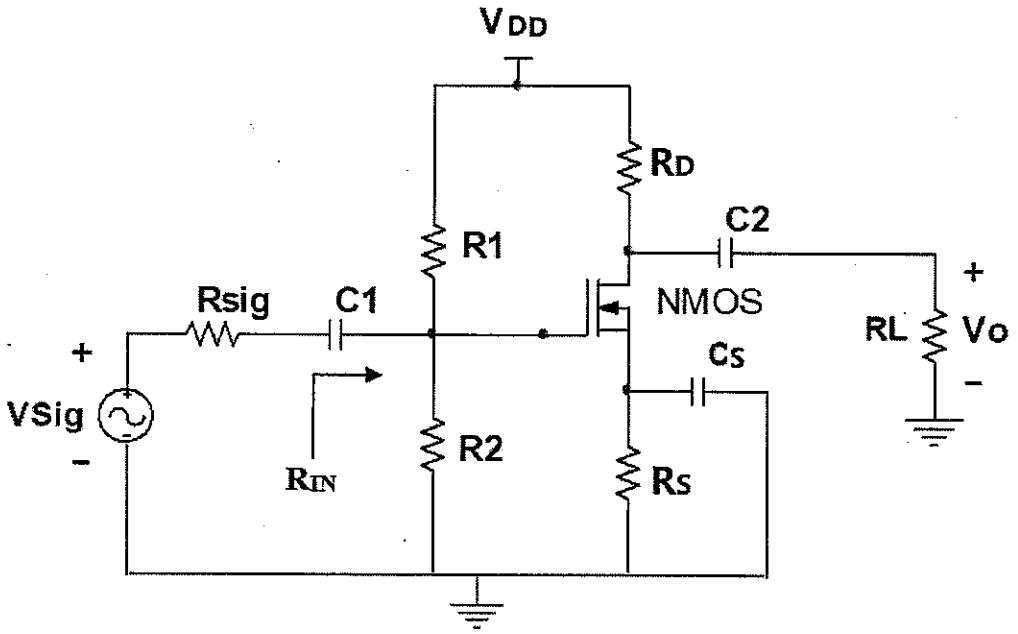

Figure Q2

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Question 3

Figure Q3 shows the NMOS differential amplifier with a current mirror as its biasing element. Assume all transistors are identical and operating in the saturation region. Given that the $(W/L)_1 = (W/L)_2 = (W/L)_3 = (W/L)_4$, $V_{DD} = V_{SS} = 12$ V, $k'_n(W/L) = 5$ mA/V^2, $V_{th} = 1$ V and early voltage $V_A = \infty$.

(a) Design the current mirror by finding the value of resistor, R1 to give the biasing current I_q to be 1 mA. [7 marks]

(b) For the differential amplifier circuit, draw the half-circuit for DC analysis. Then, determine the value of the resistors $R_{D1} = R_{D2} = R_D$ when $V_{DS} = 6$ V. [8 marks]

(c) For the differential circuit,
(i) draw the differential-mode half circuit for AC analysis, and [2 marks]
(ii) its corresponding small signal AC equivalent circuit. [2 marks]
(iii)Finally, derive the equation of the small-signal differential-mode voltage gain, A_d. [6 marks]

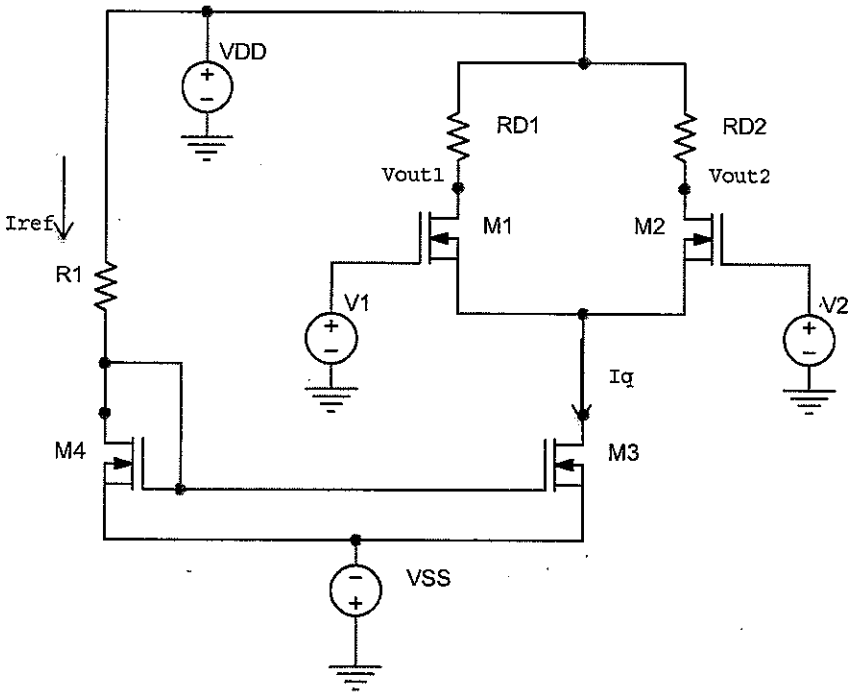

Figure Q3

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Question 4

(a) Draw a low frequency small signal equivalent circuit of the circuit shown in Figure Q4 (a) using hybrid-π model. Ignore the effect of the transistor output resistance, r_o. Then, derive the equations for the lower cutoff frequencies f_{C1} and f_{C2} of the circuits. Use necessary equivalent circuits to show in your derivations. [11 marks]

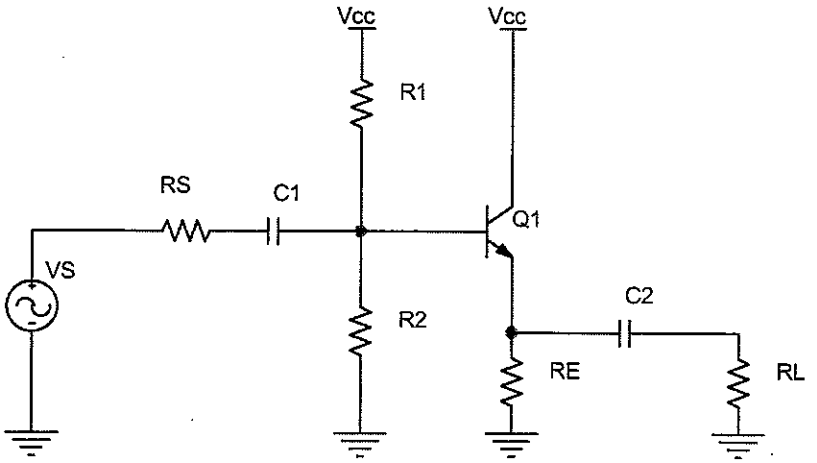

Figure Q4(a)

(b) The non-inverting amplifier shown in Figure Q4 (b) is a series-shunt feedback voltage amplifier. Derive the equations for gain A_f, output resistance R_{of} and input resistance R_{if}. Draw amplifier equivalent circuit to assist the derivations.

[14 marks]

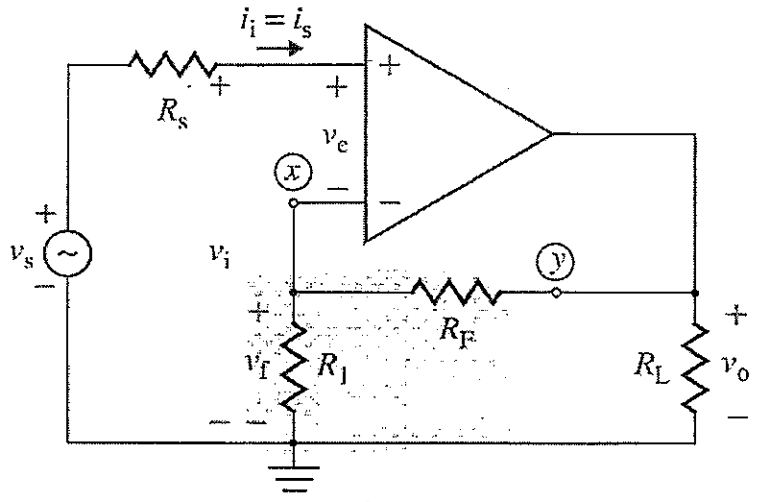

Figure Q4(b)

Continued...

Appendix: Useful formula

$$\beta = \frac{I_C}{I_B}$$

$$\alpha = \frac{I_C}{I_E}$$

$$\alpha = \frac{\beta}{\beta+1}$$

$$\beta = \frac{\alpha}{1-\alpha}$$

$$r_e = \frac{V_T}{I_E}$$

$$\alpha = g_m r_e$$

$$r_\pi = (\beta + 1) r_e$$

$$V_T = \frac{kT}{q} \approx 26mV$$

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{V_T}{I_B}$$

$$r_o = \frac{1}{\frac{\partial I_C}{\partial V_{CE}}} = \frac{V_A}{I_C}$$

$$g_m v_\pi = \beta i_b$$

$V_{DS} < V_{GS} - V_t$:

$$I_D = k'\left(\frac{W}{L}\right)\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$V_{DS} > V_{GS} - V_t$:

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

$V_{DS} > V_{DS(SAT)}$:

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2(1 + \lambda V_{DS})$$

$$V_A = V_M = L_{eff}\left(\frac{dX_d}{dV_{DS}}\right)^{-1} = \frac{1}{\lambda}$$

$$r_o = \frac{V_A}{I_D}$$

$$\phi_f = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

$$\gamma = \frac{\sqrt{2q\varepsilon N_A}}{C_{ox}}$$

$$V_t = V_{to} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$k' = \mu_n C_{ox}$$

$$V_{OV} = V_{GS} - V_t$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = k'\frac{W}{L}V_{OV} = \frac{2I_D}{V_{OV}}$$

$$C_{gs} = C_{gd} = \frac{C_{ox}WL}{2}$$

$$I_D = I_t\frac{W}{L}\exp\left(\frac{V_{OV}}{nV_T}\right)\left[1 - \exp\left(\frac{-V_{DS}}{V_T}\right)\right]$$

End of Paper